AN OVERVIEW OF VIRTUAL CITY MODELLING: EMERGING ORGANISATIONAL ISSUES

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Abstract: This paper presents a recent overview of the increasing use of Virtual Reality (VR) technologies for the simulation of urban environments. It builds on previous research conducted on the identification of three-dimensional (3D) city models and offers an analysis of the development, utilization and construction of VR city models. Issues pertaining to advantages, barriers and ownership are identified. The paper describes a case study of the development of a VR model for the city of Newcastle upon Tyne in the UK and outlines the role that academic institutions can play in both the creation and utilization of urban models. The study offers a new approach for the creation, management and update of urban models and reflects on issues which are emerging. Areas for future research are discussed.

Keywords: city models, Virtual Reality, management, diversity, ownership

1. INTRODUCTION

The production of virtual city models is an emerging concept that is being driven forward by the rapid evolution of computer technologies. The creation of such models is now being tackled by a range of city authorities, researchers and developers. The representation of an urban environment, from the aerial view maps of medieval times to the more accurate city plan projections of the Renaissance, to inexpensively produced, standardised, printed two-dimensional (2D) maps of 19th Century is not a new concept (Thompson E. *et al.* 2006). However, 3D virtual city models have emerged steadily over the last forty years following the development of suitable hardware platforms and accurate rapid-modelling methods. The introduction of Computer Aided Design (CAD) and three-dimensional computer modelling is now shaping the way in which we create and simulate our cities. Yet, like their real life equivalences, city models are never finished products (Thompson E. *et al.* 2006). With ever-changing and developing urban structures, legislations, trends and citizens' needs, city simulations have increasing need for a dynamic and

flexible platform where such modifications are possible with ease. Whilst many case studies have been reported on the creation of virtual city models, the management and update of these models has been largely neglected, partly due to their experimental nature. This paper offers an overview of the role of virtual reality (VR) in urban modelling and considers organizational issues in the adoption of VR for the representation of cities. This study also describes the development a virtual city model of Newcastle upon Tyne in the UK.

2. THREE DIMENSIONAL CITY MODELS

As information that exists about a city is hard to comprehend in its totality, good representations allow rapid understanding of the relevant features of a data-set (Whyte 2002). VR urban models have been described as computerized graphical representations or visualisations of any city and its components (Thompson E. *et al.*, 2006).

The importance of 3D reconstruction of buildings, cities and urban landscapes is becoming increasingly recognized and acknowledged (Horne 2004). The computer technology in urban planning is widely utilized in many overlapping research areas such as transportation modelling, agent-based modelling, GIS and public participation, planning and decision support, urban morphology, spatial analysis and virtual cities etc. Many cities around the world are employing real-time virtual reality technology to support the decision making process throughout the management, design and planning steps of urban environments. Much research has been conducted on 3D city models. The Corporation of London commissioned the Center for Advanced Spatial Analysis (CASA) to carry out a research of 3D models of cities and this study produced more than sixty 3D city models. According to their research these models ranged from CAD models to various 3D Geographical Information System (GIS) and Virtual Reality Mark Up Language (VRML) Web content and related simulations. Eight cities were selected for more detailed investigation. One of the most comprehensive reviews (Batty M. *et al.* 2000) was a result of the above research. Thirty-five cities with greater than one million population were listed. Table 1 shows an updated and enhanced list of city models. Urban Planners in Beirut report that a 3D computer model is now an essential tool when considering complex townscapes and planning issues (Horne 2005) and they recognize the need for a flexible tool to generate 3D massing diagrams, show the context for future developments, as well as the evolution of street landscaping and public spaces. Yet “it is still necessary to think about the amount of detail that is necessary for different applications, different phases and different target groups to be used in a 3D representation of the spatial plans” (Pleizier I. *et al.* 2004).

Currently there exist no widely accepted standardised conventions for encoding 3D virtual city models (Dollner J. *et al.* 2006). The process of generation and distribution of 3D virtual cities for government use is not obligatory and “characterised by a lively, inconclusive discussion of standards and emergence of new technologies” (Kohlhaas and Mitchell, 2007). The International Standards Organisation (ISO) and other organisations, such as the EU directive INSPIRE, have responded to this by publishing suggested standards and protocols for the formation of 3D data so that information can be shared across the internet on a global scale to access and view in a secure manner (Evans and Hudson-Smith 2005).

Table 1: Visualisation projects[1] of cities around the world

North, South and Central America	
Mexico City, Mexico	Minneapolis, USA
Santiago, Chile	New Orleans
Calgary, Canada	New York, USA
Toronto, Canada	Oakland, USA
Vancouver, Canada	Orinda, USA
Arlington, USA	Orlando, USA
Atlanta, USA	Palo Alto, USA
Austin, USA	Pearl Harbour, USA
Baltimore, USA	Philadelphia, USA
Boston, USA	Phoenix, USA
Chicago, USA	Portland, USA
Cleveland, USA	Rosslyn, USA
Dallas, USA	Sacramento, USA
Denver, USA	Salt Lake City, USA
Detroit, USA	Santa Barbara, USA
Ford Island, USA	San Diego, USA
Friday Harbor, USA	San Jose, USA
Ft Benning, USA	San Francisco, USA
Houston, USA	Seattle, USA
Jacksonville, USA	Tampa, USA
Lake Tahoe	Telluride, USA
Las Vegas, USA	Tysons Corner, USA
Los Angeles, USA	Washington DC, USA
Europe	
Hard, Austria	Amsterdam, Netherlands
Salzburg, Austria	Warsaw, Poland
Vienna, Austria	Lisbon, Portugal
Nicosia, Cyprus	Berne, Switzerland
Helsinki, Finland	Zurich, Switzerland
Paris, France	Bratislava, Slovakia
Florence, Italy	Izmir, Turkey
Parma, Italy	Bath, UK
Berlin, Germany	Bristol, UK
Bonn, Germany	Glasgow, UK
Bremen, Germany	Harrow, UK
Coburg, Germany	Hounslow, UK
Frankfurt, Germany	Leeds, UK
Giessen, Germany	Liverpool, UK
Hamburg Germany	London, UK
Heidelberg, Germany	Newcastle, UK
Hoechst, Germany	Nottingham, UK
Karlsruhe, Germany	Sheffield, UK
Munich, Germany	Slough, UK
Reutlingen, Germany	Southend-on-Sea, UK
Stuttgart, Germany	Swindon, UK
Saint Petersburg	Workington, UK
York, UK	
Asia Middle East and Africa	
Delhi, India	Tokyo, Japan
Hong Kong	Yokohama, Japan
Singapore	Beirut, Lebanon
Kobe, Japan	Al Ain City, UA Emirates
Kyoto, Japan	Dubai, U A Emirates
Australia	
Sydney	Adelaide

[1] 3D models, photogrammetric models, VR models. Information gathered from (Batty M. *et al.* 2000a), (Dikaiakou M. *et al.* 2003), (Dokonal W. *et al.* 2001), (El Araby M. *et al.* 2004), (Ftácnik M. 2004), (Hadjri K. 2004), (Horne M. 2004), (Ishida T. 2002), (Peng C. *et al.* 2002), (Piersch S. 2001), (Thompson E. *et al.* 2006), (Zipf A. *et al.* 2003), Z-mapping, 3D Web Technologies, Planet 9 Studio and Cyber City web sites.

3. EVOLUTION OF THE VISUALISATION OF CITIES

Although many cities around the world are using three-dimensional computer modelling, physical scale 3D urban models are still being used in many cases. However modifying a physical model is expensive and difficult; this method of representation is not a flexible tool to demonstrate the effects of new developments in the urban fabric. Furthermore the way to experience the city in these models is usually restricted to a "bird's eye view" which makes the assessment of implications of new developments at a human scale almost impossible (Thompson E. *et al.* 2006). These physical models require 2D plans, perspective drawings, photomontages etc to give an understanding of the complex urban structure. Despite these difficulties, wooden models are still being used and have a role to play in "considering changes at an urban scale" (Day 1994).

"Computers [2D and 3D computer aided drafting] have been used in architecture and urban planning research" (Mitchell 1996) and practice for more than four decades. Although the computer as a tool is a great help for creating accurate drawings for the proposed scheme, it is sometimes not easy to put these schemes into the urban context without the factual representation of the surrounding. Urban planning is a complex process, bringing together aspects of social, economic, physical and spatial significance (Bourdakis 1997). During this complex process of planning applications, approvals, community involvement etc, having a flexible tool to interact with different parties/stakeholders and especially with the model is very important (Figure 1).

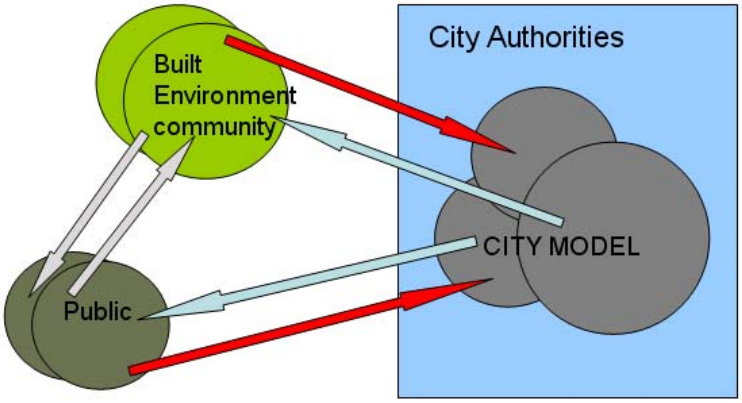

Figure 1: The current complex relationship between the parties/stakeholders for a proposed development

This interaction, accuracy and "quality of visualization" (Pleizier I. *et al.* 2004) leads to better insights and better understanding of the spatial plans and more satisfying

results for all parties involved.

The computer simulation of cities has emerged from several traditions (Day A. *et al.* 1998):

- City databases
- City maps
- City models
- City visualisations
- Representation of City behaviour

Data exchanges and analysing and observing the city model is vital for urban planning. This can be done with today's technology, which can offer a high level of visualization - an immersive and interactive virtual environment where interested parties can navigate through the city model using different hardware platforms ranging from PC screens to semi-immersive large screens to fully immersive cave automatic virtual environments (CAVE) etc.

3.1 Purposes of VR City Models

VR city models are been used to facilitate the dialogue with the local authority and the other stakeholders involved for a specific scheme and allow general debate on the city's future developments (Thompson E. et al., 2006). Additionally the visual and technical data they represent is easy to understand. "VR urban models can be used at two levels of complexity / engagement; low level, as a *presentation and evaluation tool* as well as a *planning support - analytical* tool, more advanced, real-time editing tool to be used by specially trained professionals" (Bourdakis 1997) who emphasises that "Urban models should be used to organise such information [city related information-from visitor specific aids to engineering focused information] and work as 3D fully interactive maps/indices of our cities/lives".

The 3D city model can be created for a very wide range of purposes. These have been classified into twelve different categories of use (Batty M *et al.* 2000):

- "Emergency Services
- Urban Planning
- Telecommunications
- Architecture
- Facilities and utilities management
- Marketing and economic development
- Property analysis
- Tourism and entertainment
- E-commerce
- Environment
- Education and learning
- City portals"

These categories have been enhanced and grouped into four categories (Shiode 2001) as:

- "planning and design,
- infrastructure and facility services,
- commercial sector and marketing,
- promotion and learning of information on cities"

3.2 Creation of VR City Models

Cities are complex physical and social entities. "The nature of urban environment comprises a number of elements from landscape modelling to transportation networks to various socio-economic exchanges. Every city possesses a unique structure with its own momentum" (Shiode 2001). This unique structure needs to be transferred into the digital environment realistically. In order to use VR city models in a continual process of consultation, decision making and revisions they should be based on accurate, detailed and spatially unambiguous data. The "basic steps in creating three-dimensional visualisation of landscape [and in general any digital model] are to acquire raw geographical data, process them into an appropriate form, then use them as inputs to software which will construct the three-dimensional geometry" (Discoe 2005). Consequently it can be said that data sources and choice of software and hardware plays a major part in constructing a VR city model.

Following is a summary of the digitizing / visualisation process:

- Data sources
  - Data capturing steps: aerial photography, 2D data, street level photography and laser scanning, auxiliary data, texture mapping, data processing etc.
- Software
- Accuracy level
  - Levels of abstraction / levels of detail
- City Objects
  - Terrain and sky,
  - Buildings,
  - Landmarks,
  - Vegetation and landscape modelling,
  - Street furniture, streetscape modelling
  - Populating the model with pedestrian and vehicle networks
- Monitoring, review and updating (Thompson E. *et al.*, 2006)

Table 2 illustrates stakeholders' interests in city models.

Table 2: Stakeholders' Interests in Urban Models

CITY AUTHORITIES	
Planning and Design Related Activities	Urban planning scenarios Planning and decision support Spatial analysis What if scenarios GIS applications Development control Planning permission applications Contextual modelling Traffic simulations Transportation modelling Public participation Environmental impact assessments Visual impact analysis

Infrastructure and Facility Services	Climate, air quality, fire propagate, public safety studies Emergency planning Facilities and utilities management Property management
Commercial Sector and Marketing	Marketing and advertising E-commerce
Promotion of Cities	Tourism and entertainment City portals
BUILT ENVIRONMENT SECTOR	
Base data resource	Architectural, Planning Landscape architecture and planning Construction Surveying Real Estate etc. companies
Maintenance and development plans	Gas, Electricity Phone, internet, broadband, TV
Marketing and advertising	
ACADEMIA	
Teaching and learning	Use and creation of city models City models for students projects Context analysis, mass analysis
Research, Consultancy	
Archiving	

3.3 Advantages of, and Barriers to VR City Models

The theory and practice of applying virtual reality technologies for public participation in urban design have recently been reviewed (Changfen F *et al.* 2005) and advantages of, and barriers to, have been addressed. The diverse needs of various stakeholders in the city have to be taken into consideration when generating 3D city models and urban simulations, if VR is to be adopted and used appropriately by all interested parties.

Issues that have been identified from previous research have related to the areas of ownership of such virtual cities and the need for an accurate 3D urban model to be managed by an impartial body (Pritchard 2005).

Understanding the versatile physical and socio-economical structure of a city is not always easy from a blueprint. VR urban models improve the understanding for this complex data both for lay person, and also the expert. Although the VR city models can cover large areas, parts of them can be transferred to PC or a laptop and can be used on different platforms such as networks, intranets etc which enable quick and

accurate updated information sharing. Also VR Urban models with different levels of immersiveness provide freedom of movement to its user. This freedom enables users to see and experience the model from their own viewpoint with no external participation. For different purposes (educational, municipal, commercial etc) various qualitative data can be attached to the VR models, which enables users to have instant access to diverse data. However as with most new technological developments VR urban models are facing with some technological, administrative and perception related difficulties as well. Table 3 summarize the advantages and barriers of using VR models.

Table 3: Advantages and Barriers of using VR models

Advantages of Adopting VR Urban Models	Barriers to Adopting VR Urban Models
Enhanced communication and easy to explore urban context	Technical issues (software, hardware compatibility, recurrent updating etc.)
Freedom of movement (movement between different scales and levels of details)	Organisational issues (management of shared resources, data copyright and ownership issues etc.)
Different levels of immersiveness	Ownership of the models
Ability to attach qualitative data to the models	Privacy and security
Portability	Seduction of visual images
Formally and informally sharing data with diverse stakeholders	
Ability to involve diverse disciplines together under one roof	

3.4 Ownership of VR City Models

Ownership of city models is a very complex and strategic issue involving diverse stakeholders. Authors of this paper are interested in this subject and believe that ownership issues are influencing utilisation of city models in great deal. “Academic projects have shown the potential of VR models at the urban scale and provide good case study examples, but few models built in academia are being used to their full potential in the planning process [by the relevant municipalities]. Municipal authorities are [also] beginning to use virtual reality in-house, or are working in collaboration with suppliers to develop and maintain city models” (Whyte 2002). Bringing together these individual models might answer some of the issues regarding design, production and management of the models; however this would require considerable time, effort and money from the different stakeholders. Ownership issues of some virtual city projects are outlined in the following section. This was a preliminary and limited exploration which established a foundation for a further study. It is believed that ownership of VR Urban models, and their management, are key issues for future developments and should be taken into consideration at the very early stages of model implementation.

Los Angeles

Starting from 1980s “The Urban Simulation Team’s primary focus is to build a virtual

model of the entire Los Angeles basin which can then be used to interactively fly, drive or walk-through the city. The model is constructed by combining aerial photographs with street level imagery and three-dimensional geometry to create a realistic visual simulation of the dense Los Angeles urban environment, detailed enough for the graffiti on the walls and signs in the windows to be legible" (UST no date). According to William (Bill) Jepson[2] (2006) "The UCLA Urban Simulation Lab and Bill Jepson own the complete Virtual L.A. model(s). They share non-exclusive ownership with their clients for the areas that they commission. However, that does not include any pre-existing Intellectual Property (IP) such as Urban Simulation Lab's extensive landscape, foliage and texture databases".

Helsinki

"The Helsinki City Simulator, which was presented for the first time to the public in January 2000 at the Helsinki City Planning 2000 exhibition, contains a virtual model of the Helsinki City centre and a powerful multi channel display system for real time simulation on large screen. The purpose of the simulator project was to build a realistic vision of the future city centre as it is planned today. For architects and planners a virtual model is a platform to test and improve their design. For city residents and politicians the simulator is an easy and very illustrative way to walk and fly in the future city. It provides a good basis for exchanging opinions on future design" (Suomisto 2001). Jarmo Suomisto[3] (2006) also explains their stand regarding the ownership of VR models by explaining that Helsinki virtual models are made by Helsinki City Survey Division and owned by them, they also have the rights to sell them. City Planning Department also buys the basic 3D-models and then add materials such as textures, lighting, new plans etc. Although individual modellers have no right to the model, the city planning department can use these models in their own work and give them to their planning consultants.

London

"Virtual London is a project funded by the Greater London Authority and CASA, University College of London, has been working on this project for many years. The model is being produced using GIS, CAD, and a variety of new photorealistic imaging techniques and photogrammetric methods of data capture. "The core model is aimed to be distributed via the Internet utilising techniques to optimise large urban data sets for broadband distribution" (CASA, no date). According to Michael Batty[4] the ownership of Virtual London is a very complicated issue. There are several vendors who have contributed money and data or donated software to this big project, including CASA, Greater London Authority, Ordnance Survey, Infoterra, ESRI, London Connects etc. Therefore the ownership becomes very problematic and became an issue recently when Google Earth wanted to buy this model [and we believe that still there isn't a clear answer for this problem] (Batty 2006).

Beirut

The 3D model of Beirut, recently updated because of the requirement for a visualisation of Martyrs' Square, is owned by the private sector real estate company

[2] Director of Urban Simulation Team at UCLA.

[3] Architect, Head of IT in the Helsinki City Planning Department

[4] Director of CASA

Solidere[5] which was created by Lebanese government decree in 1994 to reconstruct entire Beirut city centre, an area of 1.9 million square metres (Horne 2004). This company's role is very diverse and Solidere act as a land developer, real estate developer, property owner, property and services manager and operator. . They began developing a three-dimensional computer model in 1995 to be used as an interactive urban design tool which could be used to consider building footprint and massing options, as well as maintaining a record of floor space and proposed land use by parcel, block and sector (Gavin 1996).

4. NEWCASTLE UPON TYNE VISUALISATION PROJECT: A PILOT WORK

This project started as an experiment to extend a previously developed virtual model of Northumbria University's campus into a wider area of the city of Newcastle upon Tyne in the UK. This experiment set out to show the close relationship between the city and the campus, as well as approaches to the campus and major landmarks of the city.

4.1 Newcastle upon Tyne

Newcastle upon Tyne is a city in the North East of England with a population of 269,500 according to the 2001 census. The city is located on the northern bank of the River Tyne at latitude of 54.97°N and a longitude of 1.62°W. The Tyne gorge separates Newcastle from Gateshead, (an administratively separate borough) on the south bank. Newcastle City Council is the governing body for the metropolitan borough of Newcastle upon Tyne.

Newcastle upon Tyne has had varied identities, from Roman frontier to Norman stronghold to Great Medieval town to home of railways to industrial powerhouse to a Georgian planned town[6], which has created a rich and interesting urban texture and culture. In the nineteenth century, shipbuilding and heavy engineering were central to the city's prosperity but since the decline of such industries Newcastle has faced many challenges. Today the City Council has embarked on a major urban regeneration programme and a development framework is in place to advance the future development of Newcastle. Office, residential and retail sectors are now key industries, and major regeneration schemes are beginning to transform large parts of the city centre and contribute to its economic prosperity.

4.2 Urban and Architectural Landmarks

Newcastle upon Tyne has several urban and architectural landmarks including The Tyne Bridge, The Millennium Bridge, The Swing Bridge, The High Level Bridge, The Redheugh Bridge, Central Station, The Castle, River Tyne, Northumberland Road, Eldon Gardens, Grainger Town and Grainger Street, Jesmond Dene etc. All of these landmarks are the legacy of Newcastle's rich history. Therefore, from a modelling point of view, such landmarks should be included as a part of a VR urban model.

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[5] Solidere (Société Libanaise pour le Développement et la Reconstruction du Centre-Ville de Beyrouth), is a Lebanese joint-stock company. For more info please visit http://www.solidere.com/solidere.html

[6] Please visit for more info: http://www.newcastle.gov.uk/hods.nsf/a/histncl

4.3 Wooden City Model

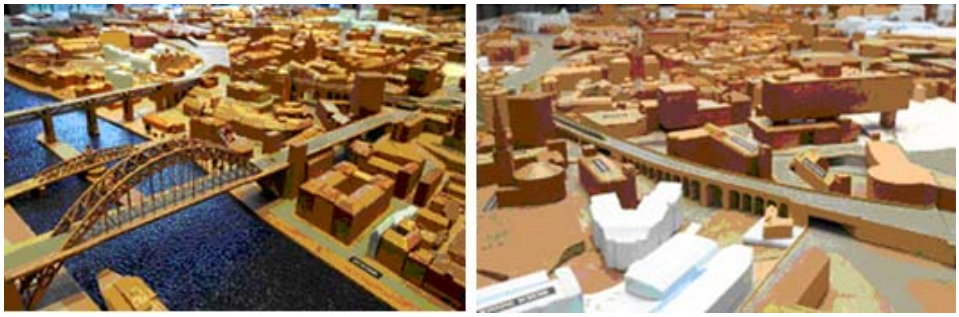

Figure 4: Newcastle Wooden Model.

The wooden, physical scale model of Newcastle has a long history. At the time of writing this model is located in the Member's Lounge in the Newcastle Civic Centre. It is of 1:500 scale and is used as a working model as well as a demonstration model. The first wooden model was created in late 1960s and since then the model has gone through several alterations and additions. At one time there were three model makers working on it. For any major development, the model makers would create updates in blue foam (to aid easy amendments etc.) and, after discussions with the architects and planners, these blue foam models were used as the basis for permanent additions to the model.

More recently, architects who propose new developments generally will have their own model makers and will create a physical scale model (often in cardboard) in the same scale of the city model to show their scheme in context. After a consultation process these models may be left attached to the city model as an update (Figure 4).

4.4 Building a Virtual Newcastle Model

The initial intention of creating the city campus model was to develop and show the close physical links between the city and the campus in a virtual model. The VR model of the Northumbria University City Campus has created great interest both from the faculty and the students and is been used for variety of purposes for teaching and learning and research in the School of the Built Environment.

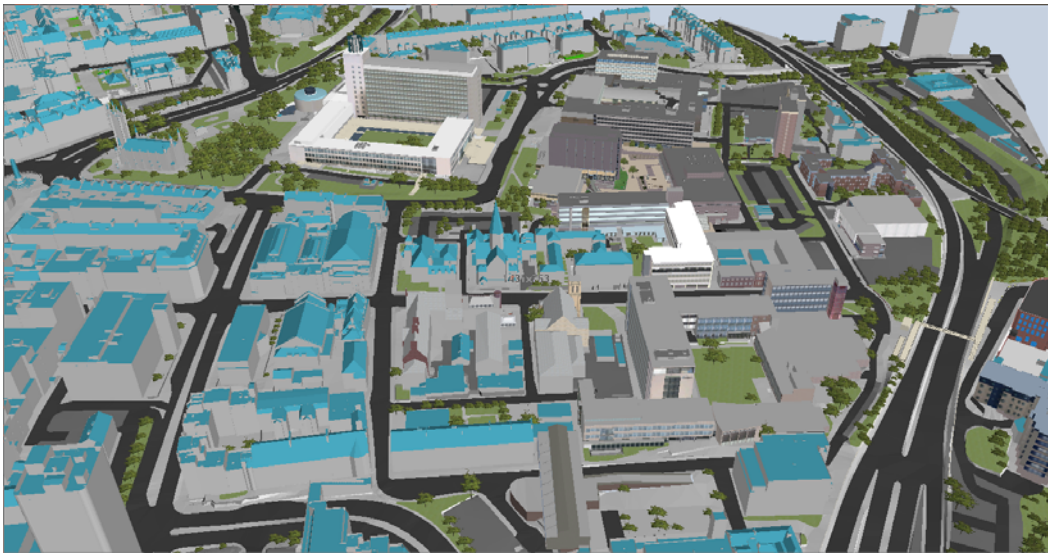

Figure 5: Newcastle VR Model.

After the completion of this pilot project; the project team[7] saw the opportunities of extending this model into a wider city model (Figure 5). 3D data was gathered from ZMapping[8] and the initial campus model data were stitched to these raw data. The method of getting the campus model into the ZMapping data was a process of isolating the elements that already been created and merging them into the city model. After the alignment of the Zmapping unit scale to the campus scale, the relevant buildings were removed and faces were isolated and detached from the main model.

Keyboard presses were then created to toggle on and off the Northumbria City Campus in the City Model to show the city model in different levels of detail.

Formal and informal meetings with various stakeholders (architects, planners, landscape architects, etc, and academics from various universities) are resulting in interest in having a virtual city model. This has led the project team to evaluate the opportunities and issues emerging, and discussions are ongoing with the City Council to exploring options for the development of a sustainable framework for the development of Virtual Newcastle.

4.5 Virtual Newcastle and Google Earth

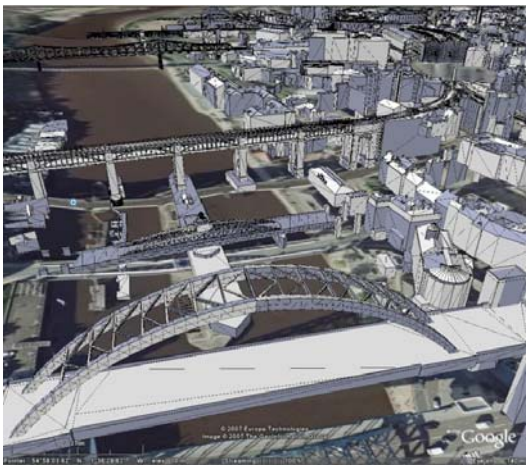

Figure 6. Newcastle VR Model placed in Google Earth

The recent introduction of Google Earth does not herald any particular advances in technology, but reflects the shift in IT towards open access to (GIS) data that can now be distributed over the web. The success of Google Earth also owes much to its interface and navigational features. 3D data can be exported into Google Earth with minimal effort, but detailed city models must be adapted and optimized to run smoothly, even using a keyhole mark-up language (KML) viewer. This highlights a current issue with the compatibility of large, detailed virtual cityscapes and the applicability of the program as a tool for detailed analysis for the built environment. More recently, the launch of Microsoft's Virtual Earth demonstrate a different approach to rapid modelling, for more realistic city models. Both of these commercial (non-specialist) approaches to GIS have focused on the user-friendliness and interactivity of geographical data. Although these virtual worlds have generated a huge amount of interest, they highlight the continued need for accurate GIS data

[7] Project team includes the academics from the School of the Built Environment and modellers from Insite Environments.

[8] For more info Please see http://www.zmapping.com/urban3dmodelling.htm

and building geometry. As both of these software giants are still in the fairly early stages of expansion into GIS, it is clear that they are in danger of becoming tools for tourism and marketing that distract the user from exploration and other functions. This can be seen in Virtual Earth where floating billboards have appeared over major cities.

Future Work

Future research will involve the further investigation of a sustainable organizational framework for the management of virtual city models. It will include the investigation and establishment of virtual city model protocols, currently emerging in the areas of

- Main model management
- Design development model management
- Planning submission management
- Scale and data co-ordinates management

The interest from diverse stakeholders regarding the creation and functionality of the VR model of Newcastle is increasing. It is believed that this will lead a more useful and flexible representation where various stakeholders can access and utilize the model according to their needs. The organisation, remote sharing and control of model data are also emerging as areas of key importance.

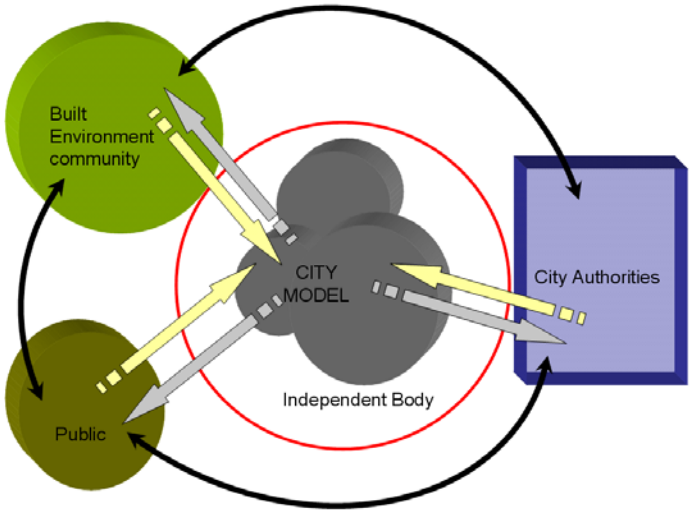

Figure 7. An alternative relationship between interested parties (Thompson E. *et al.*, 2006)

Figure 7 shows an alternative process and relationship that has been proposed to enhance the understanding and the communication between the different stakeholders in the city. With this approach, Whyte's (2002) observations on lack of utilization of models that had been created by academia, in the planning process, can be rectified if academia undertakes a coordinating role and acts as an impartial, independent body working in collaboration with all the stakeholders to maintain the city model.

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Insite Environments	http://www.insite-e.com
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